WHAT IS CLAIMED IS:

1. A three-dimensional position and orientation sensing apparatus comprising:

image input means for inputting an image acquired by an image acquisition apparatus and having at least three markers, three-dimensional positional information of which with respect to an object to be measured is known in advance;

region extracting means for extracting a region corresponding to each marker on the image;

marker identifying means for identifying the individual markers from the characteristics of the appearance of the markers in the extracted regions; and

position and orientation calculating means for calculating the three-dimensional position and orientation of the object to be measured with respect to the image acquisition apparatus, by using positions of the identified markers on the image, and the three-dimensional positional information of the markers with respect to the object to be measured.

2. A three-dimensional position and orientation sensing apparatus comprising:

image input means for inputting an image acquired by an image acquisition apparatus and having at least four markers, three-dimensional positional information of which with respect to an object to be measured is known in advance;

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region extracting means for extracting an area
corresponding to each marker on the image;

marker identifying means for identifying the
individual markers from the characteristics of the
5   appearance of the markers in the extracted regions;

marker selecting means for selecting three markers
from the markers identified by the marker identifying
means;

parameter calculating means for calculating a
10   plurality of sets of parameters for calculating the
three-dimensional position and orientation of the
object to be measured with respect to the image
acquisition apparatus, by utilizing positions on the
image of the three markers selected by the marker
15   selecting means and three-dimensional positional
information of each marker with respect to the object
to be measured; and

parameter selecting means for selecting one set of
parameters by evaluating application of the parameters
20   calculated by the parameter calculating means, to
markers not selected by the marker selecting means.

3.   A three-dimensional position and orientation
sensing apparatus according to claim 2, further
comprising parameter improving means for improving one
25   set of parameters selected by the parameter selecting
means, by evaluating the set of parameters through
application thereto of three-dimensional positional

information of each marker with respect to the object to be measured.

4. A three-dimensional position and orientation sensing apparatus comprising:

image input means for inputting an image acquired by an image acquisition apparatus and having at least three markers, three-dimensional positional information of which with respect to an object to be measured is known in advance;

region extracting means for extracting a region corresponding to each marker on the image;

marker identifying means for identifying the individual markers from the characteristics of the appearance of the markers in the extracted regions;

distance estimating means for estimating a distance to each marker based on the size of the identified marker in the image; and

position and orientation calculating means for calculating the three-dimensional position and orientation of the object with respect to the image acquisition apparatus, by using the estimated distance to each marker, a position of the marker on the image and three-dimensional positional information of this marker with respect to the object.

5. A three-dimensional position and orientation sensing apparatus comprising:

image input means for inputting an image acquired

by an image acquisition apparatus and having markers, three-dimensional positional information of which with respect to an object to be measured is known in advance;

5   image reducing means for reducing the size of the input image;

region extracting means for extracting a region corresponding to each marker on the reduced image; and

position and orientation calculating means for

10   calculating the three-dimensional position and orientation of the object with respect to the image acquisition apparatus, by using the extracted position of each marker on the image and three-dimensional positional information of each marker with respect to

15   the object.

6.   A three-dimensional position and orientation sensing apparatus according to claim 4, further comprising:

feature extracting means for extracting features

20   of the object to be measured, from the image; and

means for calibrating the position and orientation of the calculated object, from the position of the extracted features.

7.   A three-dimensional position and orientation

25   sensing apparatus according to claim 5, further comprising:

feature extracting means for extracting features

of the object to be measured, from the image; and

means for calibrating the position and orientation of the calculated object, from the position of the extracted features in the image.

5   8. A three-dimensional position and orientation sensing method for measuring the position and orientation of an object to be measured with respect to an image acquisition apparatus, by analyzing an image acquired by this image acquisition apparatus, the

10   method comprising the steps of:

inputting an image acquired by an image acquisition apparatus and having at least three markers, three-dimensional positional information of which with respect to an object to be measured is known in

15   advance;

extracting a region corresponding to each marker on the image;

identifying the individual markers from the characteristics of the appearance of the markers in the

20   extracted regions; and

calculating the three-dimensional position and orientation of the object to be measured with respect to the image acquisition apparatus, by using positions of the identified markers in the image, and the three-

25   dimensional positional information of the markers with respect to the object to be measured.

9. A three-dimensional position and orientation

sensing method for measuring a position and orientation of an object to be measured with respect to an image acquisition apparatus, by analyzing an image acquired by this image acquisition apparatus, the method

5   comprising the steps of:

inputting an image acquired by an image acquisition apparatus and having at least four markers, three-dimensional positional information of which with respect to an object to be measured is known in

10   advance;

extracting a region corresponding to each marker on the image;

identifying the individual markers from the characteristics of the appearance of the markers in the

15   extracted regions;

selecting three markers from the markers identified by the marker identifying means;

calculating a plurality of sets of parameters for calculating the three-dimensional position and

20   orientation of the object to be measured with respect to the image acquisition apparatus, by utilizing positions in the image of the three markers selected by the marker selecting means and three-dimensional positional information of each marker with respect to the object; and

25   the object; and

selecting one set of parameters by evaluating application of the parameters calculated by the

parameter calculating means, to markers not selected by the marker selecting means.

10. A three-dimensional position and orientation sensing method according to claim 9, further comprising the step of improving one set of parameters selected by the parameter selecting means, by evaluating the set of parameters through application thereto of three-dimensional positional information of each marker with respect to the object.

11. A three-dimensional position and orientation sensing method for measuring the position and orientation of an object to be measured with respect to an image acquisition apparatus, by analyzing an image acquired by this image acquisition apparatus, the method comprising the steps of:

inputting an image acquired by an image acquisition apparatus and having at least three markers, three-dimensional positional information of which with respect to an object to be measured is known in advance;

extracting a region corresponding to each marker on the image;

identifying the individual markers from the characteristics of the appearance of the markers in the extracted areas;

estimating the distance to each marker based on a size of the identified marker in the image; and

calculating the three-dimensional position and orientation of the object to be measured with respect to the image acquisition apparatus, by using the estimated distance to each marker, a position of the

5   marker on the image and three-dimensional positional information of this marker with respect to the object.

     12.   A three-dimensional position and orientation sensing method for measuring the position and orientation of an object to be measured with respect to

10   an image acquisition apparatus, by analyzing an image acquired by this image acquisition apparatus, the method comprising the steps of:

     inputting an image acquired by an image acquisition apparatus and having markers, three-

15   dimensional positional information of which with respect to an object to be measured is known in advance;

     reducing the input image;

     extracting a region corresponding to each marker

20   on the reduced image; and

     calculating the three-dimensional position and orientation of the object to be measured with respect to the image acquisition apparatus, by using the extracted position of each marker on the image and

25   three-dimensional positional information of each marker with respect to the object to be measured.

     13.   A three-dimensional position and orientation

sensing method according to claim 11, further comprising the steps of:

extracting features of the object to be measured, from the image; and

5   calibrating the position and orientation of the calculated object, from a position of the extracted features in the image.

14.   A three-dimensional position and orientation sensing method according to claim 12, further

10   comprising the steps of:

extracting features of the object to be measured, from the image; and

calibrating the position and orientation of the calculated object, from positions of the extracted

15   features in the image.

15.   An article of manufacture comprising a computer-readable recording medium having computer-readable program coding means as a processing program recorded for measuring the position and orientation of

20   an object to be measured with respect to an image acquisition apparatus, by analyzing by computer an image acquired by this image acquisition apparatus, the computer-readable program coding means comprising:

computer-readable programming means for making an

25   image to be input, the image having been acquired by an image acquisition apparatus and having at least three markers, three-dimensional positional information of

which with respect to an object to be measured is known
in advance;

computer-readable programming means for making an
area corresponding to each marker on the image to be
5   extracted;

computer-readable programming means for making the
individual markers to be identified from the
characteristics of the appearance of the markers in the
extracted regions; and

10   computer-readable programming means for making the
three-dimensional position and orientation of the
object to be measured with respect to the image
acquisition apparatus to be calculated, by using
positions of the identified markers on the image, and
15   the three-dimensional positional information of the
markers with respect to the object to be measured.

16.   An article of manufacture comprising a
computer-readable recording medium having computer-
readable program coding means as a processing program
20   recorded for measuring the position and orientation of
an object to be measured with respect to an image
acquisition apparatus, by analyzing by computer an
image acquired by this image acquisition apparatus, the
computer-readable program coding means comprising:

25   computer-readable programming means for making an
image to be input, the image having been acquired by an
image acquisition apparatus and having at least four

markers, three-dimensional positional information of which with respect to an object to be measured is known in advance;

computer-readable programming means for making a region corresponding to each marker on the image to be extracted, making the individual markers to be identified from the characteristics of the appearance of the markers in the extracted regions, and making three markers to be selected from the identified markers;

computer-readable programming means for making a plurality of sets of parameters for calculating the three-dimensional position and orientation of the object to be measured with respect to the image acquisition apparatus to be calculated, by using positions of the selected three markers on the image, and the three-dimensional positional information of the markers with respect to the object to be measured; and

computer-readable programming means for making one set of parameters selected, by evaluating the non-selected markers through application of the calculated parameters thereto.

17. An article of manufacture comprising a computer-readable recording medium storing a three-dimensional position and orientation sensing processing program according to claim 16, wherein

the computer-readable program coding means as a

processing program further comprises:

computer-readable programming means for making one set of parameters selected by the parameter selecting means to be improved, by evaluating the set of parameters through application thereto of three-dimensional positional information of each marker with respect to the object.

18. An article of manufacture comprising a computer-readable recording medium having computer-readable program coding means as a processing program recorded for measuring the position and orientation of an object to be measured with respect to an image acquisition apparatus, by analyzing by computer an image acquired by this image acquisition apparatus, the computer-readable program coding means comprising:

computer-readable programming means for making an image to be input, the image having been acquired by an image acquisition apparatus and having at least three markers, three-dimensional positional information of which with respect to an object to be measured is known in advance;

computer-readable programming means for making a region corresponding to each marker on the image to be extracted;

computer-readable programming means for making the individual markers to be identified from the characteristics of the appearance of the markers in the

extracted regions;

computer-readable programming means for making a distance to each marker to be estimated based on the size of the identified marker on the image; and

computer-readable programming means for making the three-dimensional position and orientation of the object to be measured with respect to the image acquisition apparatus to be calculated, by using the estimated distance to each marker, a position of the marker on the image and three-dimensional positional information of this marker with respect to the object to be measured.

19. An article of manufacture comprising a computer-readable recording medium having computer-readable program coding means as a processing program recorded for measuring the position and orientation of an object to be measured with respect to an image acquisition apparatus, by analyzing by computer an image acquired by this image acquisition apparatus, the computer-readable program coding means comprising:

computer-readable programming means for making an image to be input, the image having been acquired by an image acquisition apparatus and having markers, three-dimensional positional information of which with respect to an object to be measured is known in advance;

computer-readable programming means for making the

input image to be reduced;

computer-readable programming means for making a region corresponding to each marker to be extracted on the reduced image; and

5   computer-readable programming means for making the three-dimensional position and orientation of the object to be measured with respect to the image acquisition apparatus to be calculated, by using the extracted position of each marker on the image and

10   three-dimensional positional information of each marker with respect to the object.

20. An article of manufacture comprising a computer-readable recording medium storing a three-dimensional position and orientation sensing processing

15   program according to claim 18, wherein

the computer-readable program coding means as a processing program further comprises:

computer-readable programming means for making features of the object to be measured, to be extracted

20   from the image, and making the position and orientation of the calculated object to be calibrated, from a position of the extracted features.

21. An article of manufacture comprising a computer-readable recording medium storing a three-

25   dimensional position and orientation sensing processing program according to claim 19, wherein

the computer-readable program coding means as a

processing program further comprises:

computer-readable programming means for making features of the object to be measured, to be extracted from the image, and making the position and orientation of the calculated object to be calibrated, from a position of the extracted features in the image.

22. Markers having identification marks disposed on their planes, wherein

the external shapes of the identification marks are circular.

23. Markers having identification marks disposed on their planes,

each identification mark having

a background with a circular external shape, and

a plurality of predetermined patterns disposed inside this background, wherein

it is possible to identify each marker based on a combination of colors of the plurality of predetermined patterns.

24. Markers having identification marks disposed on their planes,

each identification mark having

a background with a circular external shape,

a center mark disposed at the center of the background, and

a plurality of peripheral marks disposed at equal intervals on a concentric circle encircling the center

mark, wherein

it is possible to identify each marker based on a combination of colors of the center mark and the peripheral marks.

5   25. Markers having identification marks disposed on their planes,

each identification mark having

a background with a circular external shape, and

a plurality of concentric circles with different

10   radiuses disposed inside the background, wherein

it is possible to identify each marker based on a combination of colors of areas between the concentric circles.

26. A probe to be used for measuring a position,

15   the probe comprising:

a contacting portion as a member for contacting an object to be measured; and

a mark portion having identification marks for identifying the probe disposed on the plane of the mark.

20   27. An apparatus for measuring a relative three-dimensional position and orientation of an object with respect to an image acquisition apparatus by measuring image positions of a plurality of markers mounted on the object or near the object, based on an image of the

25   markers acquired by the image acquisition apparatus, wherein three-dimensional positions of the markers are known in advance, and the measuring apparatus

comprising:

means for extracting a region corresponding to each of the plurality of markers from within the image of the markers;

5 means for identifying the individual markers by calculating geometric characteristics of the region corresponding to each of the markers within the image; and

means for estimating the relative three-
10 dimensional position and orientation of the object with respect to the image acquisition apparatus, based on the three-dimensional positions of the markers.

28. A three-dimensional position and orientation sensing apparatus according to claim 27, wherein coded
15 patterns are disposed within the individual markers.

29. A three-dimensional position and orientation sensing apparatus according to claim 27, wherein

the means for identifying the individual markers by calculating geometric characteristics of the region
20 of each marker within the image measures the size of the region of each marker within the image, and

the means for estimating the relative three-
dimensional position and orientation of the object with respect to the image acquisition apparatus calculates
25 an initial estimate of the distance between the image acquisition apparatus and a marker based on the measured value of the size of the marker region, and

calculates the relative three-dimensional position and orientation of the object with respect to the image acquisition apparatus based on the initial estimate.

30. A three-dimensional position and orientation sensing apparatus according to claim 27, wherein the image acquisition apparatus is mounted on other apparatus, and when the three-dimensional position and orientation relationship between the image acquisition apparatus and the other apparatus is known in advance or can be measured separately, the three-dimensional position and orientation sensing apparatus measures the three-dimensional position and orientation of the object with respect to the other apparatus by utilizing the relative three-dimensional position and orientation of the object with respect to the image acquisition apparatus.

31. A three-dimensional position and orientation sensing apparatus according to claim 29, wherein an estimate value is calculated by utilizing only a marker that takes a range which makes it possible to estimate the relative distance.

32. A three-dimensional position and orientation sensing apparatus according to claim 29, wherein an estimate error variance is calculated for the estimated relative distance, and the three-dimensional position and orientation of the object with respect to the image acquisition apparatus is estimated by taking both the

estimate value and the error variance into consideration.

33. A three-dimensional position and orientation sensing apparatus according to claim 29, wherein the markers are circular markers, a projected image of each marker within the image is approximated to an ellipse, and the distance from the image acquisition apparatus to each marker is estimated by utilizing the length of the long axis of the ellipse.

34. A three-dimensional position and orientation sensing apparatus according to claim 33, wherein a circular marker is utilized as each marker.

35. A three-dimensional position and orientation sensing apparatus according to claim 28, wherein a circular marker is utilized as each marker, and small patterns of different colors are used as a code within the marker.

36. A three-dimensional position and orientation sensing apparatus according to claim 28, wherein patterns of different colors are generated on a concentric circle as the maker.

37. A three-dimensional position and orientation sensing apparatus according to claim 33, wherein a three-dimensional positional sensing is carried out by adding direction information of the circular marker.

38. A three-dimensional position and orientation sensing apparatus according to claim 27, wherein for

extracting a marker region from an original image, the
apparatus generates a reduced image of the original
image, extracts a candidate region that is considered
to correspond to a marker from the reduced image,

5 calculates the area of the candidate region within the
original image, and then extracts and recognizes a
region corresponding to the marker within the original
image.

39. A three-dimensional position and orientation
10 sensing apparatus according to claim 27, wherein, after
a marker having unique geometric characteristics has
been recognized, the apparatus extracts from within the
image a separate marker having no unique geometric
characteristics, by utilizing the two-dimensional or
15 three-dimensional positional relationship of the first
marker, and updates the three-dimensional position and
orientation parameter of the object with respect to the
image acquisition apparatus, by utilizing the three-
positional position of the marker with respect to the
20 image acquisition apparatus.

40. A three-dimensional position and orientation
sensing apparatus according to claim 27, wherein the
image acquisition apparatus acquires a plurality of
images and utilizes the plurality of images.

25 41. A three-dimensional position and orientation
sensing apparatus according to claim 27, wherein
markers are mounted on the plane of a sensor probe, and

the sensor probe is used as an object to be measured,
whereby to estimate the relative position and
orientation of the sensor probe and to measure the
position of a probe tip of the sensor probe.

5   42. A three-dimensional position and orientation
sensing apparatus according to claim 29, wherein the
shapes of the markers are regular polygons.